Optimal Trajectories for Interception of Earth-Orbit-Crossing Asteroids

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Optimal (minimum-time) trajectories are determined for the interception of asteroids which pose a threat of collision with the Earth. An impulsive-thrust escape from the Earth is used initially to reduce flight time but is followed with continuous low-thrust propulsion because of the significant propellant mass advantages of electric propulsion. The initial impulsive delta-v is no larger than that used for a Hohmann transfer to Mars, e.g. that used for Mars Observer.

The continuous optimization problem is formulated as a nonlinear programming (NLP) problem using a method (referred to as "collocation") in which the differential equations of motion are included as nonlinear constraint equations in the NLP problem. In this formulation the NLP problem parameters are the state and control variables at discrete points. Polar coordinate are used so that the state variables are radius, angle, radial velocity, angular velocity, and mass. The control variables are the thrust pointing angles. The optimizer is also free to vary the launch date (in the event that waiting might improve the geometry of the intercept) and the position in Earth orbit at which the impulsive delta-v is applied. The electric motor thrust and specific impulse are assumed constant, but as fuel is consumed the thrust acceleration increases.

Initial results have been obtained only for the 2D case, i.e. assuming the asteroid orbits in the ecliptic plane. The target asteroid is #1862 with a = 1.4711 AU and e = .56016. A false initial longitude of the asteroid is chosen so that collision with the Earth will occur in 90 days. With an initial low-thrust acceleration of 0.121 milli-g interception occurs after a flight time of 84.6 days. Assuming an I_{sp} of 1000 sec the final thrust acceleration is 1.753 milli-g; thus approximately 11% of the spacecraft mass, after escape from the Earth, remains at interception of the asteroid.